HARMON

Shearing Strength of Concrete

Civil Engineering

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SHEARING STRENGTH OF CONCRETE

BY

IVAN GUY HARMON

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1907

1907
H52

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C O L L E G E O F E N G I N E E R I N G

May 24, 1907.

This is to certify that the following thesis prepared under the direction of Professor A. N. Talbot, Head of the Department of Municipal and Sanitary Engineering, by

IVAN GUY HARMON

entitled SHEARING STRENGTH OF CONCRETE

is accepted by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker

Head of Department of Civil Engineering

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SHEARING STRENGTH OF CONCRETE

INTRODUCTION

The recent growth in the use of concrete has created a great demand for more information concerning its strength under many conditions and its various methods of failure. Modern competition in structural work has naturally been the cause of much investigation along lines of economical design, so that in the last few years reinforced concrete has taken a prominent place among building materials.

Formerly when simply plain concrete was used, the designs were often governed by the maximum bending moment, and a section large enough to care for the maximum bending moment was undoubtedly large enough to care for any shear that might occur at the supports. The tensile and compressive strengths of concrete of various mixtures and of various ages were well defined by the experiments of many able investigators. But for the reasons shown above experiments on the shearing strength of concrete have been very few, and the conditions and methods governing practically all of the experiments that have been made were of such a nature as to render the results of little value. Since the adoption of the use of reinforced concrete and the natural diminution of the area of sections, the safety of the structures depends

almost entirely on the values assumed for the shearing strength of the concrete.

The values for shearing unit-stress that have been obtained by various experimenters vary from values less than the tensile strength to values almost as much as the compressive strength. Before briefly describing and comparing the leading experiments that have been made on concrete in shear, it must be said that there exist and have existed among these experimenters various conceptions of the nature of the shearing action. Shear is defined "to be the action of two equal and oppositely directed forces whose lines of action are in planes very close together." It is hardly probable that in actual structures or even in test pieces this condition will actually exist. However, test pieces approximate this condition, and the forces used in the analysis are theoretically as above defined. Shear must be considered as having some uniformity of distribution over the sheared surface, and this distribution so far as is now known is considered as practically uniform. It can now be seen that great care must be taken to distinguish between shear and its accompanying phenomena, such as tension, cutting action, bearing action, and diagonal tension.

One of the first experiments on the shearing strength of mortar and concrete was made by Bauschinger in

1878[1]. The material was mortar and the specimens tested were 2.4 in. by 4.8 in. and 12 in. long. The pieces were tested in flexure, and the results were interpreted to show that the shearing strength of the mortar was 20% greater than its tensile strength. It is probable that tension and not shear was the controlling element in the failure. Professor C. B. Smith made experiments on test pieces composed of three bricks cemented together, the middle one projecting beyond the other two and the load being so applied as to avoid transverse bending. These tests are of very little value on account of the dissimilarity of the materials used. Marsh quotes Feret[2] as concluding "that the ultimate shearing strength is proportional to that for compression and obtains the relation that the shearing strength is 0.16 to 0.20 of the compressive strength." M. Considere gives the value of the shearing strength of concrete as 20% to 30% higher than the tensile strength. The latter values are considerably higher than those found by Feret. These two men, however, agree in allowing a working unit shearing strength equal to 1/8 of the ultimate unit compressive strength, or about 50 lbs. per sq. in. This is the value for shear adopted by the New York City Building Code and by several eastern railroads. Very little is known of the methods of failure and loading used in the experiments from

[1]Sabin's Cement and Concrete, p. 328.
[2]Marsh's Reinforced Concrete, p. 222.

which these data were taken, and as such forces as diagonal tension and shear were not then as fully understood as at present, it is not at all unlikely that some such manner of failure governed. The very low values obtained are the basis for this assumption.

Falk's[1] experiments give values of 10% to 18% of the compressive strength of concrete as its shearing strength. The methods of testing were such that the loads produced a high cutting action, thus opening these experiments to criticism.

Lately Professor Spofford conducted some tests at the Massachusetts Institute of Technology, from which he concluded that the shearing strength of concrete and mortar is very near 50% of the direct compressive strength. The specimens were 5 in. in diameter and 15 in. long, held in cylindrical bearings 5 1/2 in. apart, the load being applied through a half-cylindrical bearing 5 7/8 in. in length. It is possible that tension was an element in the failure, and that the shearing values so obtained are small. It is also possible that the confining action of the cylindrical bearings may not have permitted the proper expansion and have set up combined stresses.

The most recent experiments that have been made

[1] Falk's Cements, Mortars and Concretes, p. 95.

have been made at the University of Illinois and are fully described in Bulletin No. 8 of the University of Illinois Engineering Experiment Station. The principal test pieces used were recessed blocks, both plain and reinforced, and the restrained beam. These tests gave values averaging from 50% to 75% of the compressive strength as the shearing strength. These values are not inconsistent with the values obtained by Professor Spofford. The recessed block or punching test is open to criticism because the shearing stress is not uniformly distributed over the area of failure and because the specimen can not freely expand laterally. In the restrained beam tests both tension and bearing failures were unmistakably very frequent. The application of the load at the top of the specimen, as was done in these tests, does not permit of even distribution over the shearing area.

It should be noted that none of the above mentioned data was taken from short time specimens. All the data were from specimens over thirty days old. Within the last few years many failures of reinforced concrete buildings and other structures have occurred. In many cases the failure was caused by too early removal of forms. In other words, the strength of concrete only a few days old is not well defined and evidently is being assumed too high. For this reason tests were made on specimens of 7 days as well as of 60 days

of age.

The tests recorded in this thesis were made in an attempt to determine the shearing strength of concrete of various mixtures and of various ages. Experiments were made on two new forms of test pieces and these test pieces were designed with the purpose of eliminating the objectionable features, such as tension, excessive bearing stresses, non-uniform distribution of stress and confinement against expansion, of test pieces used in other experiments.

Tests were also made on the plain punching specimen as used by Schoeller and Seavert in 1906, in order to get a comparison of results under the same conditions. Tests were made on compression specimens in order to get the ratio of the shearing strength to the compressive strength of concrete of the same ages and mixtures.

DESCRIPTION OF MATERIALS

In order to get results consistent with common practice, the materials used were of the regular trade quality, the cement being purchased in the open market.

Stone

The stone used was Kankakee limestone. It contained 35% voids. The following table gives the fineness test of stone:

T A B L E I

FINENESS TEST OF STONE

Size of Sieve in Inches	First Test		Second Test	
	Per Cent Passing	Per Cent Caught	Per Cent Passing	Per Cent Caught
1 1/4	100	0	100	0
1	95	5	95	5
1/2	40	55	29	66
1/4	~~75~~ 7	32	2	27
1/8	~~25~~ 3	5	1	1
Pan	...	3	...	1

Sand

The sand was of good quality, sharp, clean, and rather coarse. It contained 29% voids. The following table gives the fineness test of sand:

T A B L E 2

FINENESS TEST OF SAND

Sieve Number	First Test		Second Test	
	Per Cent Passing	Per Cent Caught	Per Cent Passing	Per Cent Caught
5	99.8	.1	99.5	.2
10	80.8	19.0	80.0	19.5
12	73.8	7.0	71.2	8.8
16	67.4	6.4	63.4	7.8
18	52.9	14.5	48.2	15.2
30	26.2	26.7	25.9	22.3
40	15.0	11.2	16.1	9.8
50	5.4	9.6	7.6	8.5
74	1.9	3.5	3.6	4.0
Pan	....	1.9	....	3.6

Cement

The cement used was Chicago AA Portland, purchased from a local dealer. The following table gives the fineness test of cement:

T A B L E 3

FINENESS TEST OF CEMENT

Sieve Number	First Test		Second Test	
	Per Cent Passing	Per Cent Caught	Per Cent Passing	Per Cent Caught
50	100.0	0.0	100.0	0.0
74	100.0	0.0	99.9	0.1
100	97.0	3.0	97.0	2.9
200	81.75	15.25	78.75	18.25
Pan	.....	81.75	.....	78.75

The tensile strength of neat cement at age of 7 days was 379 $\pm$ 25 pounds per square inch, and at age of 28 days it was 616 $\pm$ 20 pounds per square inch. The tensile strength of 1:3 mortar at age of 7 days was 171 $\pm$ 13 pounds per square inch, and for an age of 28 days it was 325 $\pm$ 20 pounds per square inch, 6 briquettes being tested in each case.

Concrete

The sand and cement were mixed dry. The stone was then added and the whole mixture turned several times, after

which the water was added and the mass thoroughly mixed. Enough water was used so that it would flush to the top after light tamping.

DESCRIPTION OF TEST SPECIMENS

In order to be of any value it was necessary that the faults of previous test pieces should be in a large measure corrected in any specimen that should be adopted. It was decided first to adopt something on the plan of a simple beam. In order that a test piece along this line should be of any value it seemed that it was necessary to increase the tension area and decrease the shearing area sufficiently so that the section must fail by shear before a tension crack would appear. The bearing area must also be increased in order to prevent the crushing action often met with, and have a specimen of such form that no restraining force would be necessary during a test. A uniform distribution of stress must also be approximated. A section which it was believed would fulfil all these conditions was designed and is shown in Plate 1 , page 27 , and Sketch 1 , page 28 . In testing, the load was applied uniformly over the middle section by means of a saddle, as shown in Plate 1 , page 27 . It can be seen at once that the section gives an exceptionally small shearing area compared with the bearing and tension areas. Care was taken to make the side slopes of the section steep enough to

prevent the lower corners under the saddles from shearing off. The load is directly applied over 15/22 of the perimeter of the sheared section.

The forms used for making these specimens were necessarily complex. Each form was composed of 17 pieces, and it was necessary to take the form entirely apart to remove the specimen. Drawing of form is shown in Sketch 2 , page 29 . These forms were entirely of soft pine. This specimen will be known as Class A.

The second specimen adopted was of such form that it would fail by torsion. It was thought that if the specimen were circular with a much reduced section at the middle, it must necessarily fail at this point. It was also thought that if the length of the reduced section were limited to about two inches, the failure must occur within this length and the failure would be due practically to shear. The turning force was applied to the section sheared through an iron casting inserted in each end of the specimen, thus producing a uniform distribution of the load. The form of this test piece is shown in Plate 2 , page 30 , and in Sketch 3 , page 31 . A circular hole 1 1/2 in. in diameter ran through the center of the specimen lengthwise. This was done in order to permit expansion of the concrete toward the center as well as away from it. Obviously there will not be an even distribution of

stress over the shearing area in this form of test piece.

The forms used for this test piece were of galvanized iron and allowed easy removal. Sketch of forms is shown on page 32 . This form of test piece will be known as Class B.

The other specimen adopted was the same as one form used by Schoeller and Seavert in their tests in 1906 and described in their thesis. It was simply a recessed block through which a hole was punched in testing. In this specimen the inside is a beveled circular hole 6 1/8 in. in diameter at the top and 7 in. in diameter at the bottom, by 2 in. deep. This test piece is shown in Sketch 5 , page 33 . The application of the vertical load tends to punch the concrete within the shearing section. This tendency is resisted by the surrounding concrete and induced tension is the result. This specimen will be known as Class C.

The forms used in making the specimens of Class C are shown in Sketch 6 , page 34 . The base platform was 18 in. by 20 in. and consisted of two 10 in. by 3/4 in. planks fastened together by 2 in. by 2 in. cross sticks, which served as rests so that the platform did not rest upon the floor. To the center of this platform was screwed a conical block 2 in. thick and 6 1/8 in. small diameter by 7 in. large diameter. It was sawed in three pieces as shown in Sketch, in order to allow easy removal. The inside dimensions were 12 1/2 in. by 12 1/2 in.

Twenty-four specimens were made of each class, twelve being of 1:2:4 mixture and twelve of 1:3:6 mixture. Of each twelve six were tested at an age of 7 days and six at an age of 60 days.

In placing the concrete in the forms it was thoroughly tamped and spaded in order to give a uniform section and smooth surfaces.

All specimens were left in their forms 6 days, and the 7-day specimens were then left in open air until tested. The 60-day specimens were stored in damp sand after the forms were removed and left there until tested.

The specimens used in the compression tests were the standard 8-inch cylinders, 16 in. long. Three cylinders were made from each batch of concrete mixed. See Plate 7, page 39.

The forms used for the cylinders consisted of two semicircular pieces of iron 16 in. long, which fitted into a bed-plate and were held together by means of an iron band, as shown in Sketch 7, page 40.

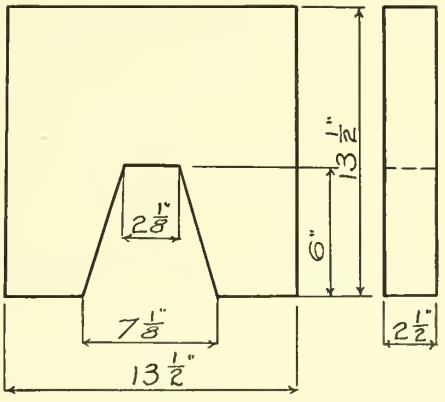
DESCRIPTION OF TESTS

The tests on Classes A and C and the compression tests were made on an Olsen machine of 200,000 lbs. capacity. The slowest speed was used, it being 0.04 in. per minute. The tests on Class B were made on an Olsen torsion machine. The

minimum graduations on the moment scale were in 50 lb.-in. This was entirely too large to be used with this class of specimens, so the load was applied as usual by one head of the machine, but the second head simply supported the other end of the specimen and the moment was registered by means of a lever arm fastened to a square iron bar inserted in the specimen, the opposite end resting on a pair of scales.

In the shear test loads were applied continuously up to the ultimate load, the first appearance of cracks being carefully noted. All accompanying phenomena were carefully noted.

The loads were applied to specimens of Class A through a steel saddle shown in the accompanying sketch to the right. Each end of the specimen was supported in a saddle of the same dimensions. The middle saddle was carefully centered and one edge of each of the supporting saddles was placed as nearly on the shearing line as possible. The load was transmitted through a spherical bearing block to the central saddle. See Plate 1, page 27. In order to get an even bearing between saddle and specimen plaster of paris was applied to the bearing surfaces and allowed to set under a light load for about five minutes.



In testing specimens of Class B, a 1 1/4-inch square iron bar was inserted in the castings in the ends of the specimens (shown on Plate 2 , page 30 . At one end of the specimen the protruding end of the bar was centered in the head of the machine, and at the other end it rested in a piece of pipe which was centered in the other head of the machine. This piece of pipe served as a support, but at the same time permitted the iron bar which was inserted in it to turn freely. The lever arm was 29 in. long from the center of the specimen to the bearing point on the scales. The load was applied very slowly in order to get accurate measurements. The arrangement of the lever arm and scales is shown on Plate 2 , page 30 .

In testing the specimens of Class C, the recessed area was placed down and the load applied through a circular bearing block, 5 7/8 in. in diameter, centered over the recessed area. Plaster of paris was used on all bearing surfaces and the load applied as shown on Plate 3 , page 35 . The speed used in these tests was the slowest possible, 0.04 in. per minute.

In testing the cylinders for compression, the bearing surfaces were set in plaster of paris and the load applied through a bearing block, as shown on Plate 7 , page 39 . The speed used was 0.04 in. per minute.

OBSERVED PHENOMENA

Class A (Beam Specimens)

The first signs of failure in specimens of Class A (Beam Specimens) were different for the 7-day tests and the 60-day tests. In the former a small crack first appeared completely outlining the section over which failure finally occurred. At the first appearance of this crack the scale beam suddenly dropped, showing the ultimate load. This crack would then widen uniformly around the section until complete failure occurred. Cracks did not appear at any other point on the specimen, even after complete failure. When broken the sheared surface did not present an appearance such as might be expected if tension had been the cause of failure; that is, the stone and mortar were equally visible on both surfaces. There was probably some crushing at the edges of the saddle through which the load was applied, but it was so little that it produced no distinct phenomena. After the ultimate load had been reached it was necessary to run the machine five to ten minutes before final rupture. Every one of the specimens of this age and class failed in this way.

In the tests on the 60-day specimens of this class no warning cracks appeared. Without any warning phenomena at all, the center section would suddenly drop and the supporting saddles be thrown outward. The failure in every case was squarely along the shearing plane. No accompanying cracks

could be seen on the specimen after failure. The stone and mortar were equally distributed over the adjacent surfaces after failure, showing the absence of pure tension. The appearance of the sheared surfaces and the method of failure of these specimens are shown on photograph, Plate 4 , page 36 .

Class B (Torsion Specimens)

In specimens of Class B no cracks appeared before final rupture. Complete failure occurred at the instant the ultimate load was reached. Contrary to expectations failure did not occur in a plane perpendicular to the reduced area. The crack along which failure occurred in all cases began at one end of the reduced area and gradually wound around the reduced area in the distance of two inches, thus forming a spiral. The center of the supports and the center of the specimens were carefully centered in the same line so that this method of failure could hardly be due to eccentric loading. In all cases the adjacent surfaces after rupture presented very dissimilar appearances; all the stone being on one surface and all the mortar on the other. This may prove that tension was the governing factor in these failures. The method of failure is shown on photograph, Plate 5 , page 37 .

Class C (Punching Specimens)

In specimens of Class C, from one-third of the

maximum load up to within a few hundred pounds of the maximum load, cracks developed near the middle of all four sides of the rectangular specimen, starting from the bottom and gradually increasing until the top was reached. The cracks spread toward the center and gradually widened to about 1/16 in. at failure. The cracks formed so as to leave the specimen in five parts after failure. This method of failure is well shown on Plate 6 , page 38.

Compression (Cylinders)

No "first signs of failure" were noted in the cylinders before the complete failure at the maximum load. At the time the first cracks appeared the scale beam dropped, thus showing the ultimate load. The cracks at failure ran lengthwise of the cylinder and were very fine. Failure seemed to be due to a bursting or expanding action. This failure occurred in all cases very near the middle of the length of the cylinder.

COMPUTED DATA

Tables 4 to 17 , pages 41 to 47 give the results of the tests recorded in this thesis. A summary of the results is given in the following table:

T A B L E 1 8

SUMMARY OF SHEAR TESTS

Form of Specimen	Age of Specimen	Kind of Concrete	Method of Storing	Number of Tests	Strength lb. sq. in.		Ratio of Shear to Compression
					Shear	Compression	
Class A (Beam)	7	1:2:4	Air	6	92	501	18.4%
Class A (Beam)	7	1:3:6	Air	6	63	360	17.5%
Class A (Beam)	60	1:2:4	Damp Sand	6	252	1039	24.2%
Class A (Beam)	60	1:3:6	Damp Sand	6	140	620	22.6%
Class B (Torsion)	7	1:2:4	Air	6	106	501	21.2%
Class B (Torsion)	7	1:3:6	Air	5	58	360	16.7%
Class B (Torsion)	60	1:2:4	Damp Sand	5	197	1039	19.7%
Class B (Torsion)	60	1:3:6	Damp Sand	5	121	620	19.6%
Class C (Recessed Block)	60	1:2:4	Damp Sand	3	500	1039	48.7%
Class C (Recessed Block)	60	1:3:6	Damp Sand	3	408	620	65.9%

Class A (Beam Specimens)

The unit shearing stress for specimens of Class A is found by dividing the total stress by twice the reduced area between the two trapezoidal sections.

Class B (Torsion Specimens)

The method for computing the unit shearing stress for specimens of Class B is as follows:

Take specimen BI for illustration. The exterior or twisting moment causing failure must be equal to the internal or resisting moment. The scale load is 64 lbs. and the moment arm is 29 in., giving an exterior moment of 1856 lb.-in. The interior moment is given by the formula $\frac{Ss \times J}{c}$, where Ss is the unit shearing stress at the extreme fiber, J is the polar moment of inertia of the section, and c is the distance from the center of the section to the extreme fiber. J is equal to $\frac{3.1416 \times Diam.^4}{32}$

Then, $\frac{Ss \times 3.1416 (D^4 - d^4)}{32} = 2.21 \times 1856$

$Ss = 113$ lb. sq. in.

Class C (Punching Specimens)

The unit shearing stress for specimens of Class C is found by dividing the total load by the area found by multiplying the circumference of the recessed area at its smallest diameter by the perpendicular distance from the top of the

recessed area to the top of the specimen.

Compression Specimens

The unit compressive strength is found by dividing the total load by the area of the 8-inch cylinder.

CONCLUSION

The tests on the specimens of Class A and Class B give very low unit shearing stresses. This may be accounted for to some extent by the fact that the concrete used in these tests was only about 50% as strong as that used in the tests of 1906. However, the comparative results are among the lowest ever found, the unit strength in shear varying from 17% to 24% of the unit compressive strength. Mr. Richardson, Class of 1907, made tests on the flexural strength of concrete of 1:2:4 mixture at an age of 60 days and obtained a flexural unit strength of 250 lbs. per sq. in. From this it is seen that the shearing unit strength and the flexural unit strength are practically the same for specimens of Class A, and the shearing unit strength for specimens of Class B is only about 80% of its flexural strength. The specimens of Class C gave unit shearing stresses of 49% and 66% of the compressive strengths. The methods of failure and the results agree with those obtained by Schoeller and Seavert in 1906. These results are also consistent with those obtained by Feret and Spofford.

From the summary it is noted that so far as these

tests are concerned the value of the shearing unit strength of concrete of various ages and mixtures varies directly with the compressive strength, with the exception of specimens of Class C, ranging from 17% to 24% of the compressive strength. It should be noted that these percentages are exceptionally uniform. It is commonly understood that the strength of concrete in compression is influenced very largely by the strength of the cement. Professor Talbot, in Bulletin No. 8 of the University of Illinois Engineering Experiment Station, states that "the resistance of concrete to shear is dependent upon the strength of the stone as well as upon the strength of the mortar, and for the richer mixtures the strength of the stone probably has the greater influence". Reasoning backward from this statement, inasmuch as the strength of specimens of Classes A and B varied uniformly with the compressive strength, their strength must be dependent in a very great degree on the strength of the cement. Then failure must have been due to other influences than shear.

With the exception of the specimens of Class C all the failures were at lower values than any of the noted experimenters, with the exception of Falk, have yet found. Falk gives values for shear of 1:3:5 concrete at an age of 120 days of 158 lbs. per sq. in., or 18% of the compressive strength. Falk's experiments are open to criticism on account of the

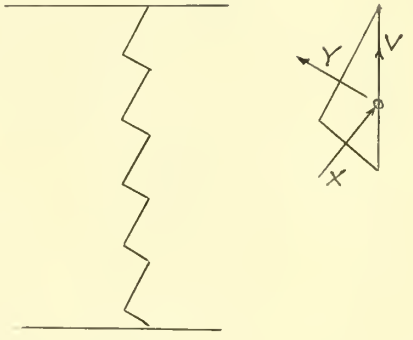
great bearing and cutting action set up in testing.

From the above comparison of data and from the facts that the 1:2:4 mixture ran the same in shear as the flexural strength, and that throughout the tests the strength of the cement seemed to be the governing feature in failure, tension or combined stresses of some nature must have been the real cause of failure.

Specimens of Class B are believed to have failed by diagonal tension. The reasons for this conclusion are: First, that a crack appeared at one point and gradually lengthened, winding itself around the section in the form of a spiral, at the same time increasing in width; and second, that the mortar on the section of failure pulled away from the stone, thus leaving a predominance of stone on one of the faces after failure.

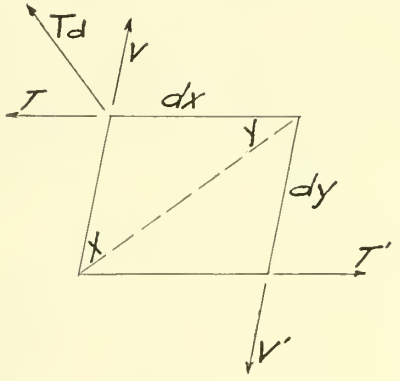
The tests on specimens of Class A for the various mixtures and ages were but very little higher than those of Class B, showing that they must have failed by some other method than shear. However, as before stated, no accompanying cracks, other than the one along the line of failure, attended failure. So far as known, tension cracks always appear when failure occurs by tension, and they are of such a nature as to be easily detected. Attempts to reconcile these various facts are futile, and it must be stated that the method of

failure of specimens of this class of specimens is unknown. It is believed that failure was due to a saw-tooth tearing action along the plane of failure. This failure may have begun on the inside and have been such that the outside cracks were the last phenomena, or failure may have occurred over the whole section at once. When the load was applied stresses probably were set up along many different lines, and these stresses may have been of several kinds. It is believed that these forces were resolved along lines normal to planes which were so inclined as to produce a saw-tooth appearance after failure. All the stress created in the section must be taken up by the concrete. In the sketch to the right suppose failure to occur along the planes as shown. Then the forces causing failure are X and Y, each normal to its plane. X would be tension and Y compression. The true shearing stress would be the vertical components of these forces. It may be seen that the conditions of loading and the forms of test pieces may be such that the slopes of the planes of failure would vary, X and Y would vary, and in turn V be made larger or smaller. The smaller V was in comparison with H the greater tension would influence



failure.

Another method of showing this action is as follows: Assume a small rectangular section of concrete of unit width, having a length of dx and a depth of dy. The shearing forces V and V' will tend to deform the section as shown in the sketch to the right. This will induce the horizontal stresses T and T' which tend to prevent the deformation. The stresses T and T' are tensile forces. Taking moments about one of the corners,



$$V\ dy\ dx = T\ dy\ dx$$

$$V = T$$

V and T combine to form a diagonal tensile stress Td tending to produce tension over the area xy. The unit stress Td also equals the unit stresses T and V. In the punching tests the stress T is taken up by the concrete surrounding the section of failure.

There can be no shear without accompanying stresses of various natures. The nature of these stresses we do not know. However, it appears that where the accompanying stresses are taken up by concrete or steel, other than that at the section of failure, we get the high values of shear as found in the plain and reinforced recessed block tests. But, where the accompanying stresses are taken up by concrete at the critical

section, failure usually is due to some form of tension and we get low values in shear.

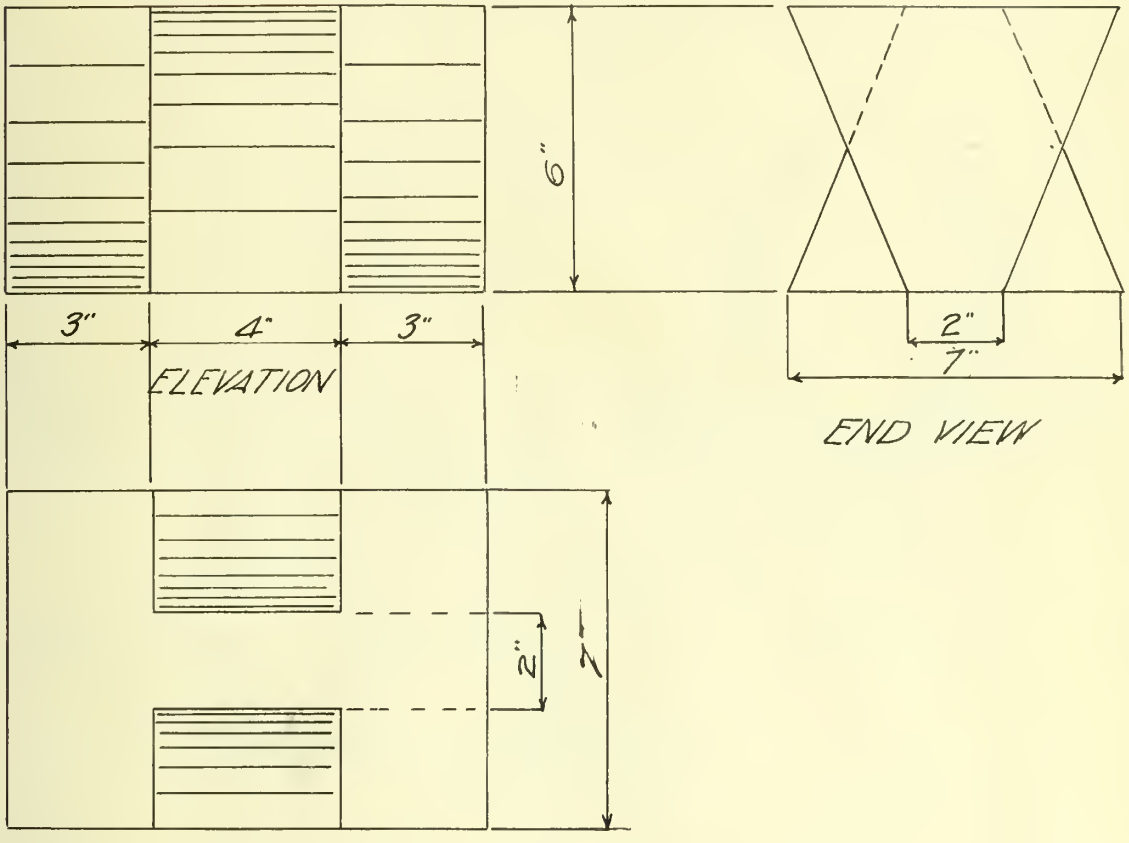
Note: Suggestions for the analyses were taken from the recent work on concrete by Professor E. Mörsch of the Technical Institute of Zürich, Germany.

Plate 1

Method of Testing
Shear Specimen, Class A.

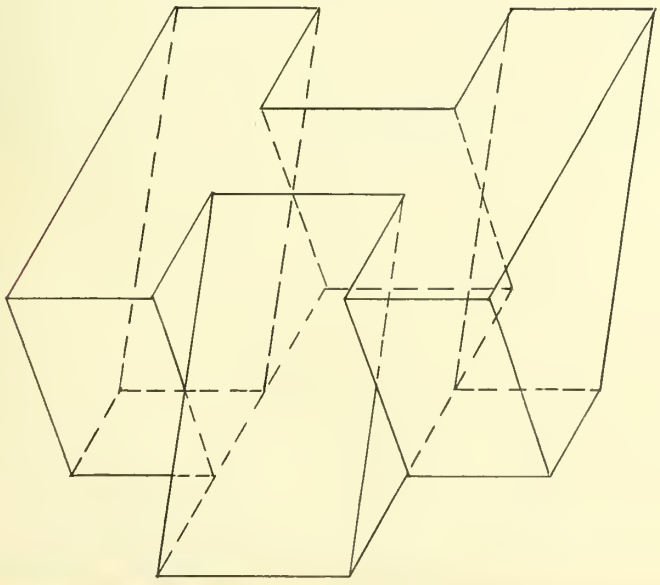
Sketch 1

SHEAR SPECIMEN
CLASS A



PLAN

ISOMETRIC



Sketch 2 (29)

SHEAR SPECIMEN FORMS

CLASS B

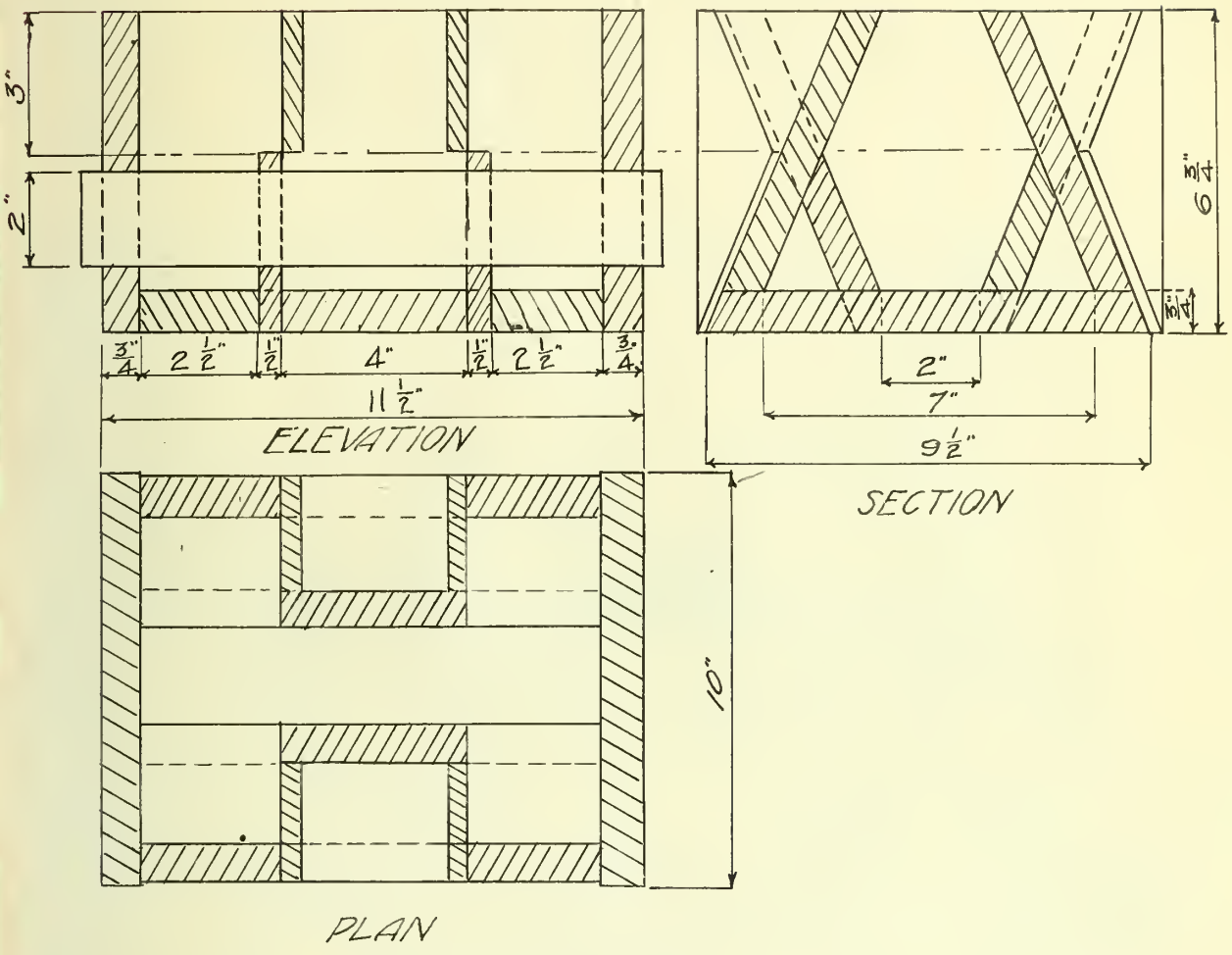
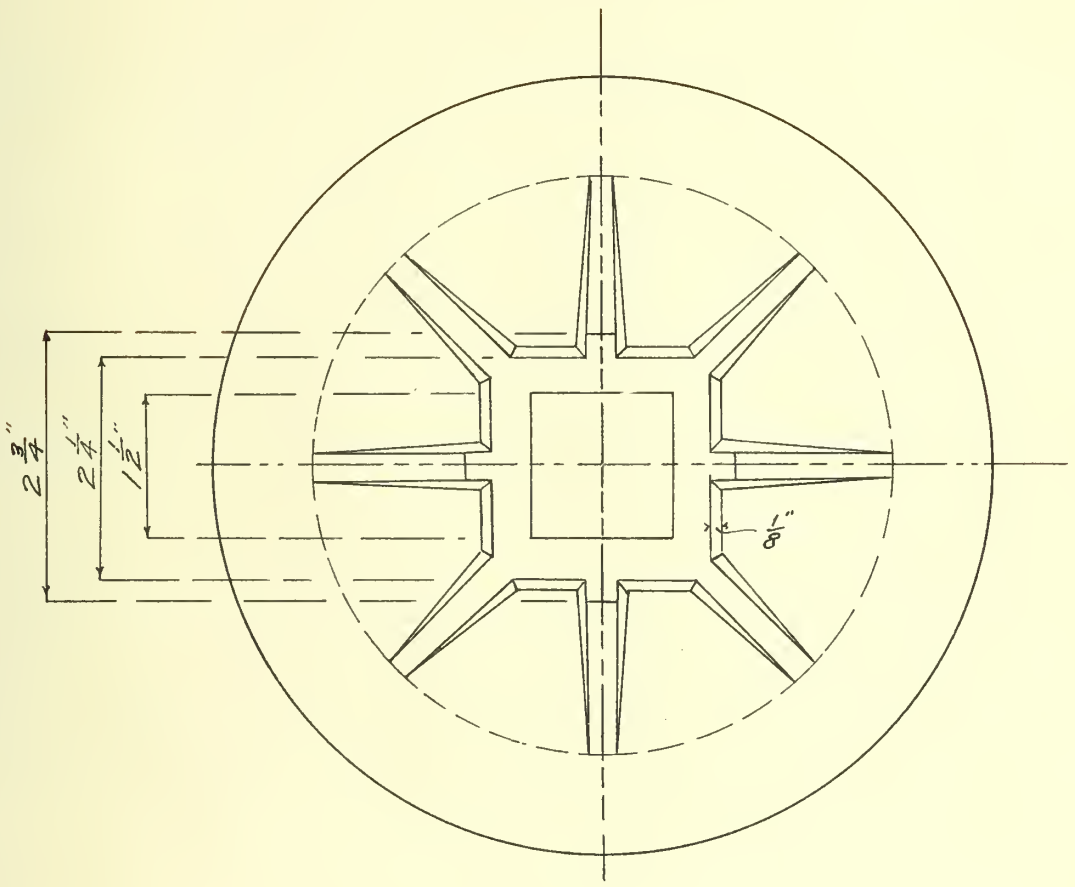


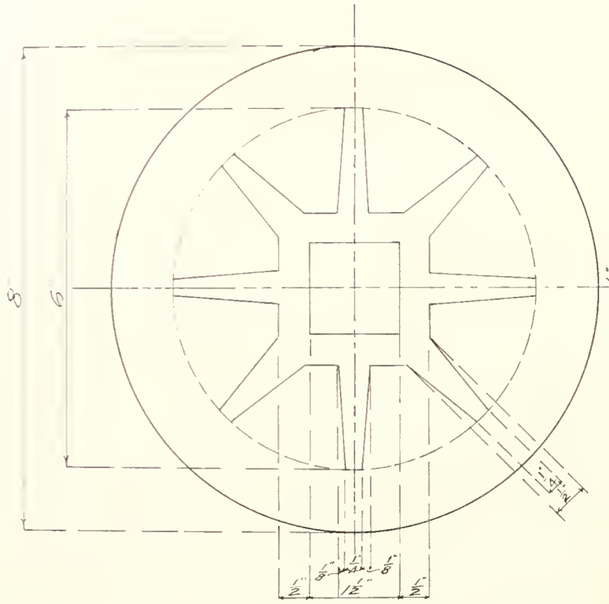
Plate 2

Method of Testing
Shear Specimen. Class B

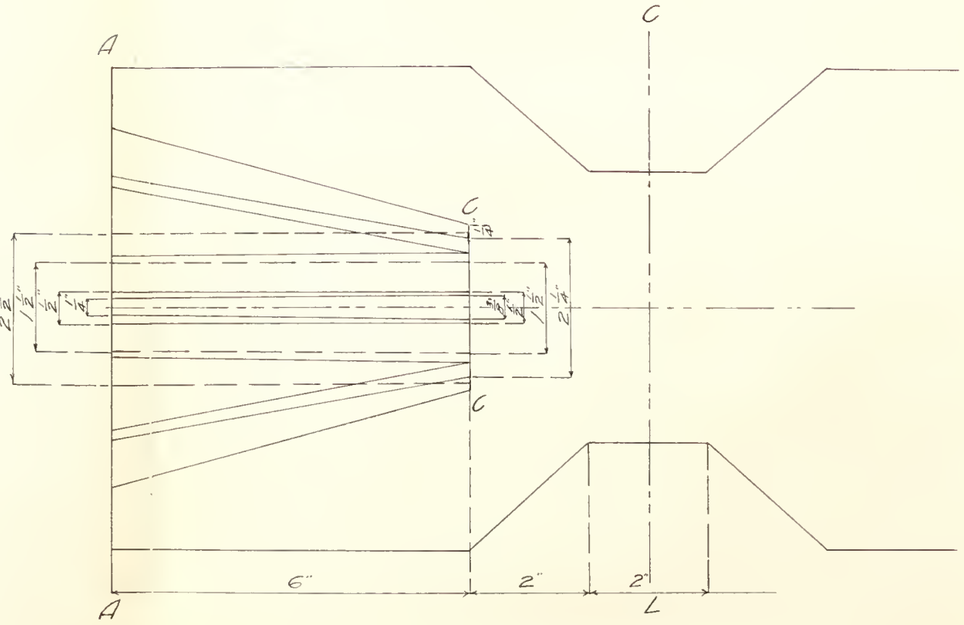


SECTION C-C

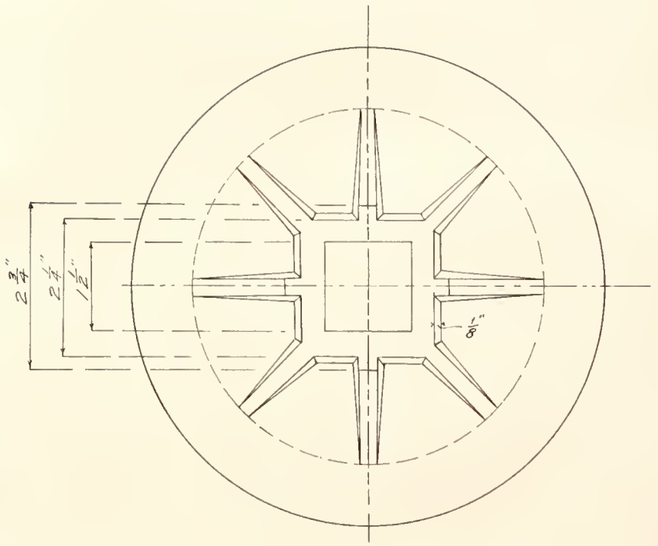
TORSION SPECIMEN, CLASS B



END VIEW A-A



PLAN

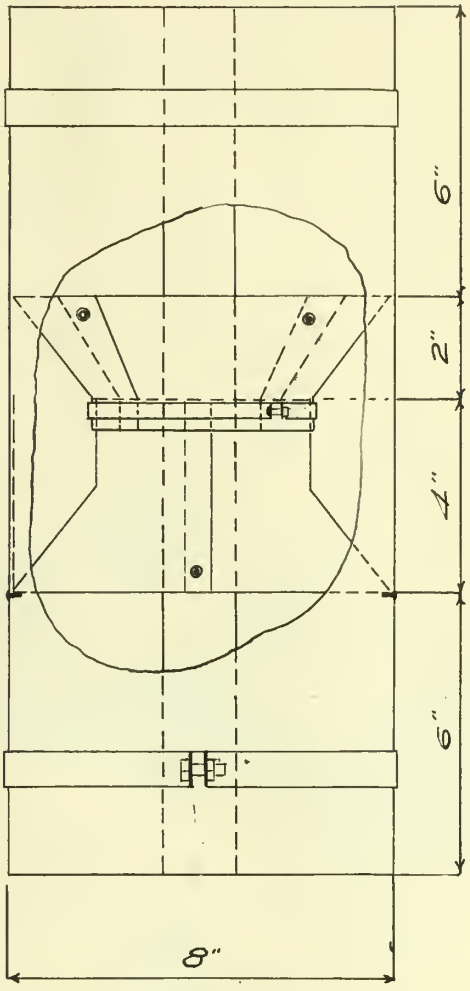


SECTION C-C

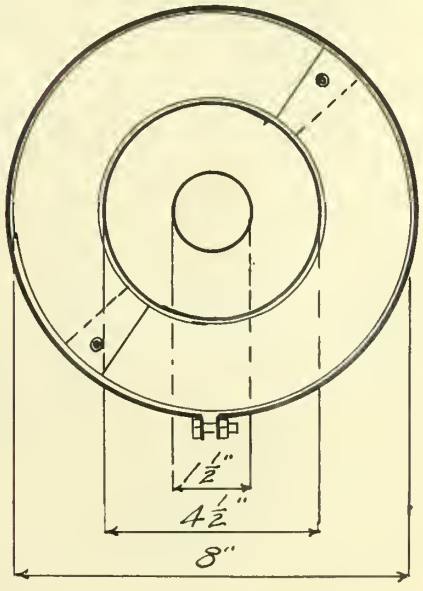
Sketch 4

SHEAR SPECIMEN FORMS

CLASS B



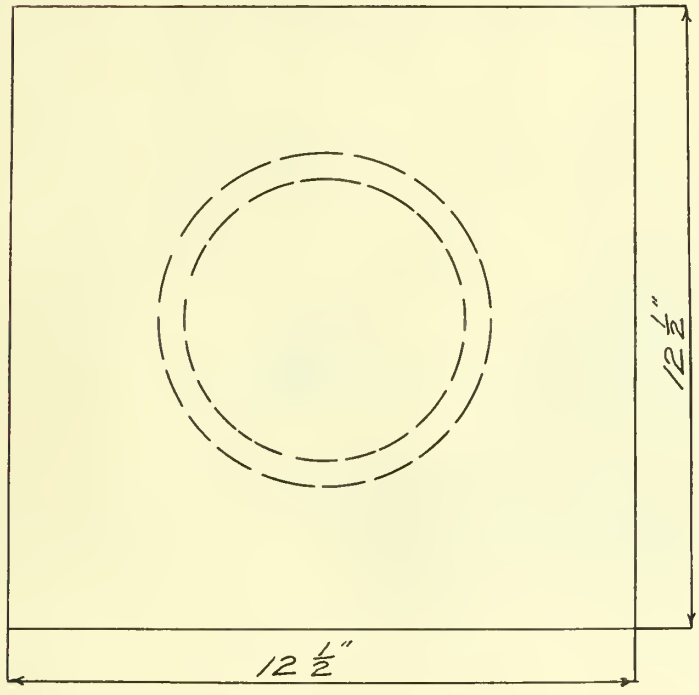
ELEVATION



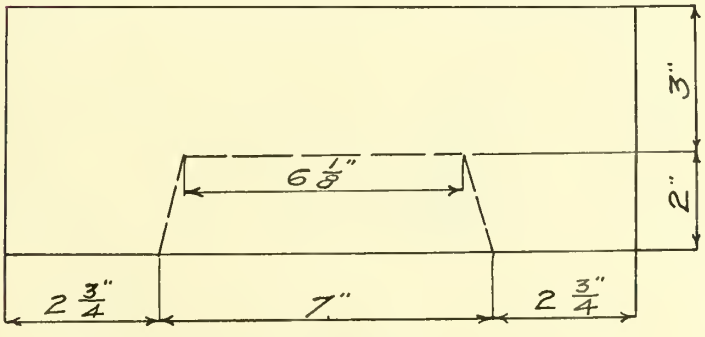
PLAN

Sketch 5

SHEAR SPECIMEN
CLASS C



PLAN

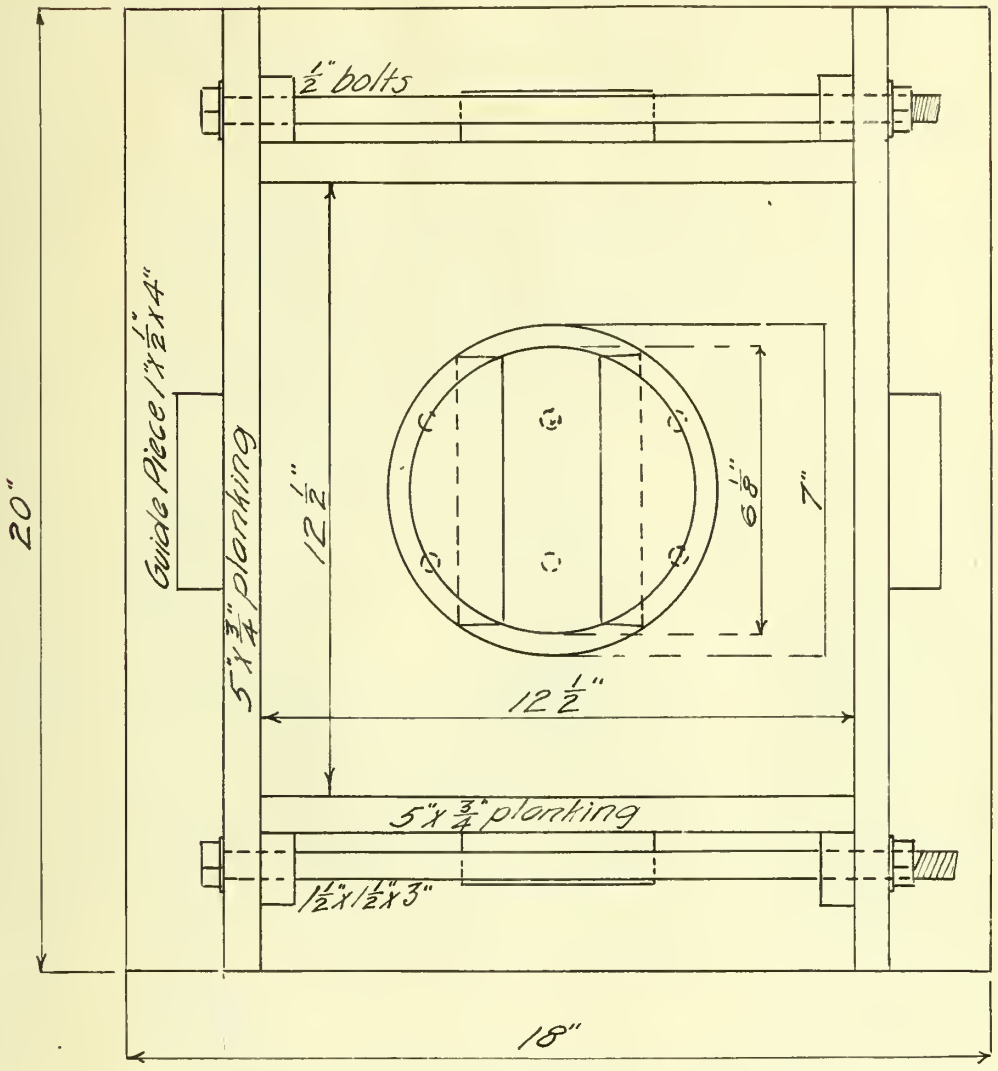


ELEVATION

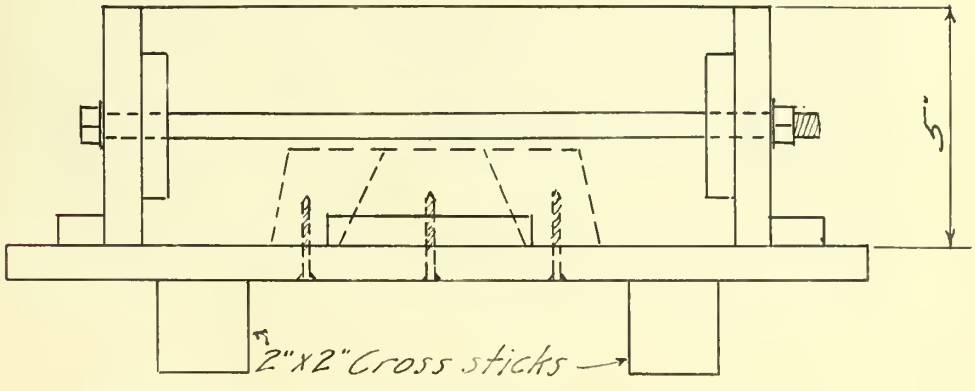
Sketch 6

FORMS FOR SHEAR SPECIMEN

CLASS C



PLAN



ELEVATION

Plate 3

Manner of Failure and Method of Loading

Shear Specimen, Class C.

Plate 4

Method of Failure
Shear Specimen, Class A

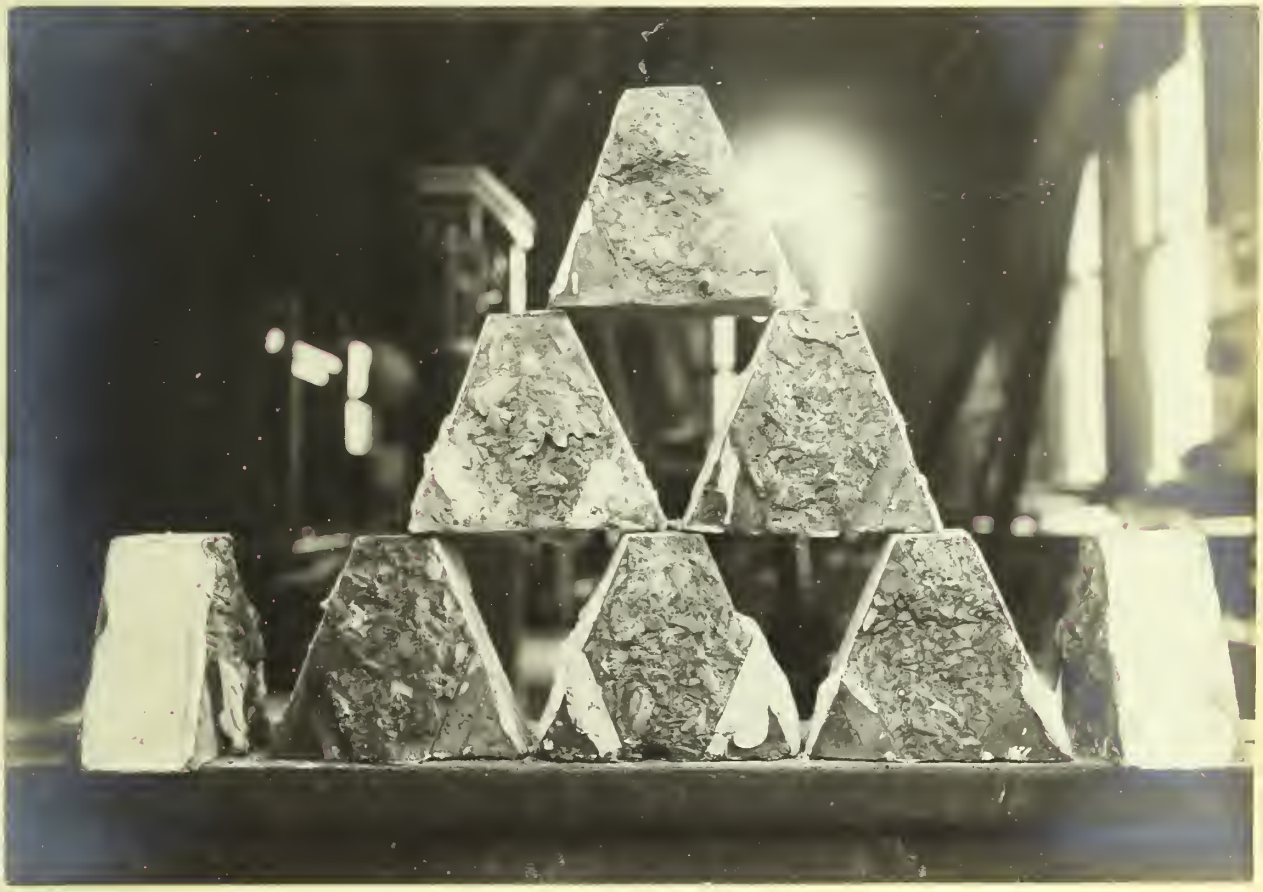


Plate 5

Method of Failure

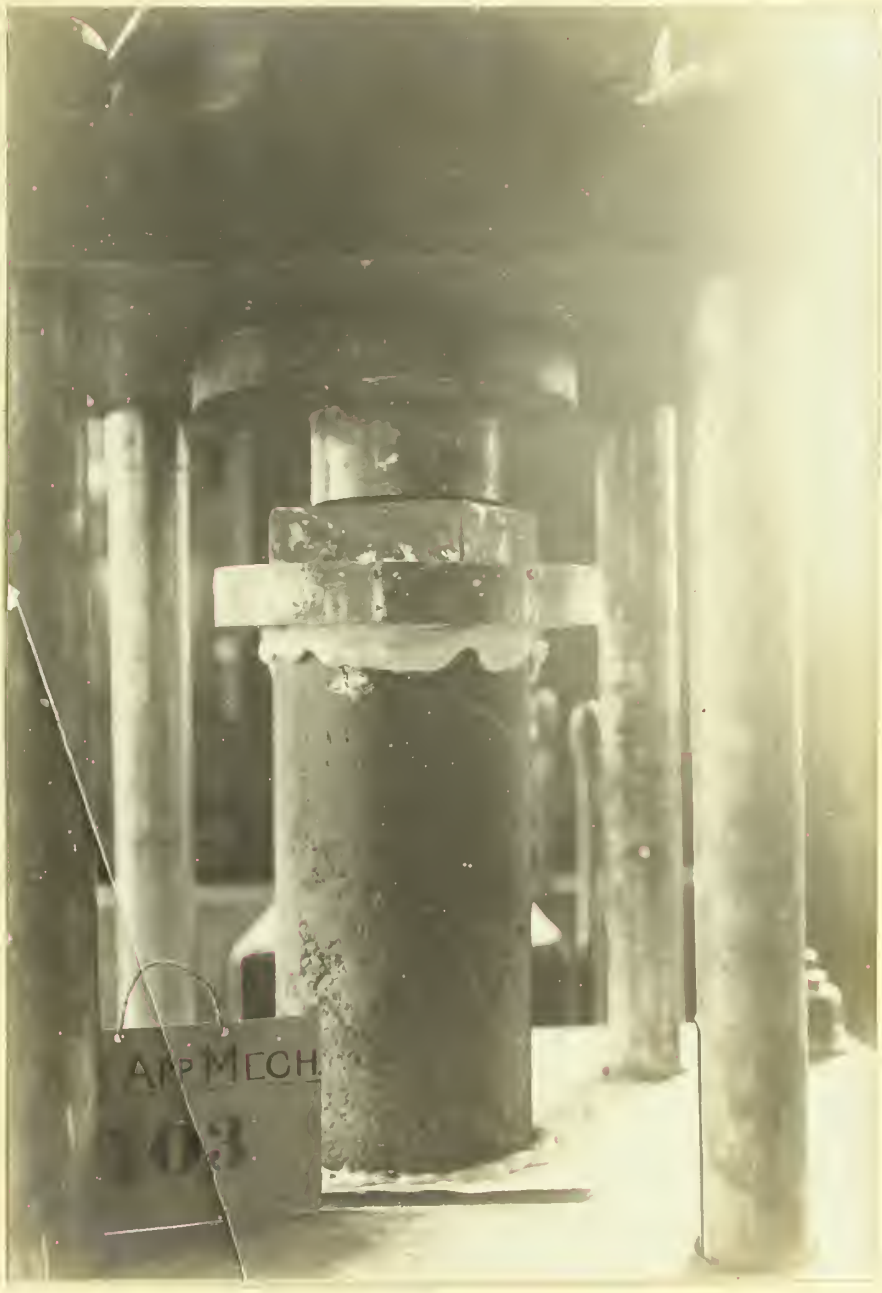
Shear Specimen, Class B

Plate 6

Method of Failure
Shear Specimen, Class C.

Plate 7

Method of Testing Cylinders.



Sketch 7.

CAST IRON FORM FOR CYLINDERS

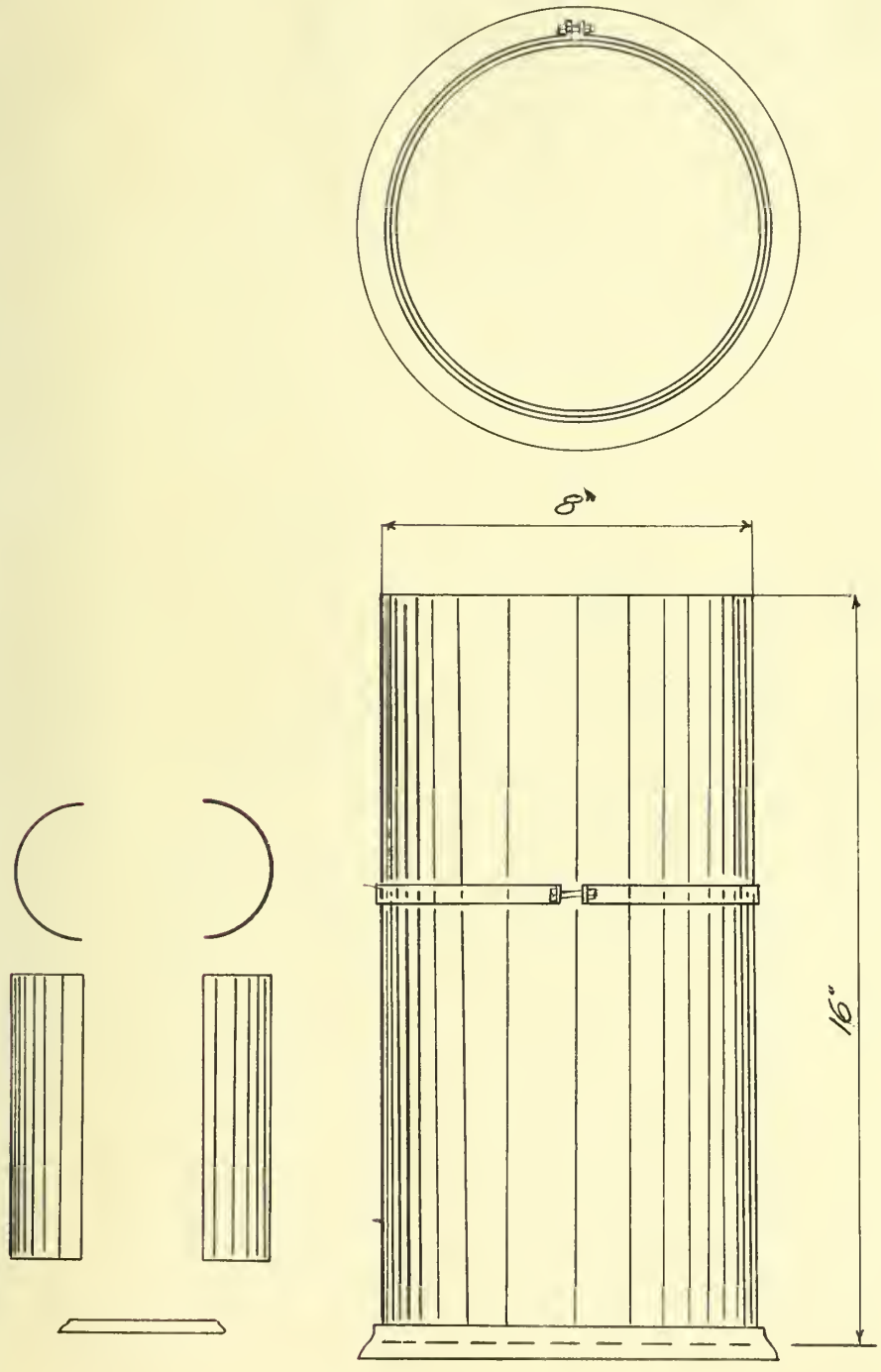


TABLE 4

Shearing Strength of Concrete

1:2:4 Concrete Age 7 days.

Class A. Beam Specimen

Ref. No.	Shearing Section in sq. in.	Load in Pounds		Unit Shearing Stress lb. sq. in.
		First Crack	Ultimate	
1.	39.	4020	4020	103
2.	39	3400	3400	87
3	39	4050	4050	104
4.	39	3060	3060	79
5	39	3670	3670	94
6	39	3260	3260	84
		Mean		92

TABLE 5

Shearing Strength of Concrete

1:3:6 Concrete Age 7 days.

Class A. Beam Specimen

Ref. No.	Shearing Section in sq. in	Load in Pounds		Unit Shearing Stress lb. sq. in.
		First Crack	Ultimate	
7	39	2120	2120	54
8	39	2360	2360	61
9	39	2820	2820	72
10	39	2480	2480	64
11	39	2770	2770	71
12	39	2150	2150	55
		Mean		63

TABLE 6

Shearing Strength of Concrete

1:2:4 Concrete Age 60 days

Class A. Beam Specimen

Ref. No.	Shearing Section Sq. in.	Load in Pounds		Unit Shearing Stress lb. sq. in.
		First Crack	Ultimate	
13	39	11620	11620	298
14	39	9980	9980	256
15	39	9600	9600	246
16	39	10280	10280	262
17	39	8260	8260	212
18	39	9220	9220	236
			Mean	252

TABLE 7

Shearing Strength of Concrete

1:3:6 Concrete Age 60 days

Class A. Beam Specimen

Ref. No.	Shearing Section Sq in.	Load in Pounds		Unit Shearing Stress lb. sq. in.
		First Crack	Ultimate	
19	39	5880	5880	152
20	39	4920	4920	126
21	39	5420	5450	140
22	39	4720	4720	121
23	39	6050	6050	155
24	39	5720	5720	148
			Mean	140

TABLE 8

Shearing Strength of Concrete

1:2:4 Concrete Age 7 days

Class B. Torsion Specimen

Ref. No.	Outside Diam. in in.	Shearing Area in sq. in.	Load on Scales in lb.	Moment of Inertia	Unit Shearing Stress lb. sq. in.
1	4.42	13.6	64	37.0	113
2	4.35	13.2	48	35.4	87
3	4.45	13.9	45	39.0	75
4	4.45	13.9	73	39.0	123
5	4.45	13.9	79	39.0	134
			Mean		106
6	4.40	13.6	13		

TABLE 9

Shearing Strength of Concrete

1:3:6 Concrete Age 7 days

Class B. Torsion Specimen

Ref. No.	Outside Diam. in in.	Shearing Area in sq. in.	Load on Scales in lb.	Moment of Inertia	Unit Shearing Stress lb. sq. in.
7	4.35	13.2	38	35.4	68
8	4.45	13.9	36	39.0	56
9	4.45	13.9	41	39.0	67
10	4.40	13.6	30	36.9	52
11	4.50	14.2	28	40.3	45
			Mean		58
12	4.35	Broke	Handling		

TABLE 10

Shearing Strength of Concrete

1:2:4 Concrete — Age 60 days

Class B. Torsion Specimen

Ref. No.	Outside Diam. in in.	Shearing Area in sq. in.	Load on Scale in lb.	Moment of Inertia	Unit Shearing Stress lb. sq. in.
13	4.50	14.2	126	40.3	204
14	4.40	13.6	116	36.9	201
15	4.45	13.9	117	39.0	194
16	4.45	13.9	101	39.0	167
17	4.50	14.2	134	40.3	218
				Mean	197
18	4.40		Defective		

TABLE 11

Shearing Strength of Concrete

1:3:6 Concrete — Age 60 days

Class B. Torsion Specimen

Ref. No	Outside Diam. in in.	Shearing Area in sq. in.	Load on Scales in lb	Moment of Inertia	Unit Shearing Stress lb sq. in.
19	4.45	13.9	60	39.0	100
20	4.40	13.6	76	36.9	134
21	4.50	14.2	80	40.3	131
22	4.35	13.2	74	35.4	133
23	4.45	13.9	64	39.0	107
			Mean		121
24	4.40		Defective		

TABLE 12
Shearing Strength of Concrete
1:2:4 Concrete Age 60 days
Class B. Punching Specimen

Ref. No.	Shearing Section			Total Load in Pounds		Unit Shearing Stress
	Diam. in.	Thickness in.	Area sq. in.	First Crack	Ultimate	lb. sq. in.
1	$5\frac{7}{8}$	$3\frac{1}{8}$	57.8	21200	27450	475
2	$5\frac{7}{8}$	$3\frac{1}{8}$	57.8	19600	28420	493
3	$5\frac{7}{8}$	$3\frac{3}{16}$	58.8	17020	31200	531
					Mean	500

TABLE 13
Shearing Strength of Concrete
1:3:6 Concrete Age 60 days.
Class C. Punching Specimen

Ref. No.	Shearing Section			Total Load in Pounds		Unit Shearing Stress
	Diam. in.	Thickness in.	Area sq. in.	First Crack	Ultimate	lb. sq. in.
4	$5\frac{7}{8}$	$3\frac{1}{8}$	57.8	12240	22860	396
5	$5\frac{7}{8}$	$3\frac{1}{8}$	57.8	16920	24240	421
6	$5\frac{7}{8}$	$3\frac{1}{8}$	57.8	17410	23560	408
					Mean	408

TABLE 14
Compressive Strength of Concrete
1:2:4 Concrete Age 7 days
Cylinders, 8 in. x 16 in.

Ref. No.	Compression Area sq. in.	Total Load lb. sq. in.	Unit Load lb. sq. in.
1 A-B	50.3	25670	512
2 A-B	50.3	27690	550
3 A-B	50.3	22090	440
		Mean	501

TABLE 15
Compressive Strength of Concrete
1:3:6 Concrete Age 7 days
Cylinders. 8 in. x 16 in.

Ref. No.	Compression Area sq. in.	Total Load lb. sq. in.	Unit Load lb. sq. in.
4 A-B	50.3	18000	358
5 A-B	50.3	17120	341
6 A-B	50.3	19180	382
		Mean	360

TABLE 16

Compressive Strength of Concrete

1:2:4 Concrete Age 60 days

Cylinders 8 in. x 16 in.

Ref. No	Compression Area sq. in.	Total Load lb. sq. in	Unit Load lb. sq. in.
7 ABC	50.3	51840	1030
8 ABC	50.3	55800	1110
9 ABC	50.3	49130	976
		Mean	1039

TABLE 17

Compressive Strength of Concrete

1:3:6 Concrete Age 60 days

Cylinders 8 in. x 16 in.

Ref. No.	Compression Area sq. in.	Total Load lb. sq. in.	Unit Load lb. sq. in.
10 ABC	50.3	28200	560
11 ABC	50.3	33740	671
12 ABC	50.3	31640	630
		Mean	620

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